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REPORT

ON

A BACTERIOLOGICAL INVESTIGATION OF DUBLIN MILKS

AND

THE PURE MILK PROBLEM.

BY

JOSEPH W. BIGGER, M.D., D.P.H.

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PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

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No. 4622/1921.
Dublin County Borough.

LOCAL GOVERNMENT BOARD,
DUBLIN, 2*nd May*, 1921.

SIR,—I am directed by the Local Government Board for Ireland to transmit, for the consideration of the Corporation of Dublin and the Public Health Committee, the accompanying copy of a report prepared by the Board's Bacteriologist, Dr. J. W. Bigger, detailing the results of a comprehensive survey of the quality of milk as ordinarily supplied for public consumption in Dublin. Dr. Bigger's observations and conclusions will readily appeal to the expert reader, but the technical form in which they are properly and necessarily expressed will probably present difficulties to those who are unfamiliar with scientific terminology. It is unnecessary to dwell upon the deep concern which the quality of the milk supply possesses for all classes and sections of the population, and it is with a view to rendering the position clear to the average citizen that the following summary and comments are offered.

The study is based on milk samples to the number of one hundred obtained in the usual course of delivery in the City of Dublin through the agency of the Food Inspectors of the Corporation over a period from August, 1919, to July, 1920, and may therefore be taken as fairly representative of the character of milk as customarily purveyed for general consumption. The samples were tested for micro-organisms capable of growing at a temperature of blood heat, and the bacterial content was reckoned on that basis. The various milks were found to show very wide differences in the number of total organisms contained, quite apart from variations of season. There is in general a considerable tendency for the figures to be higher in the warmer months of the year than in the cooler, the summer average for total organisms being nearly seven times that of the winter. The lowest monthly average figure was for December, from which there was each month, with the exception of June, an increase up to the maximum in August, followed by a steady return to the December average. The general results cannot be described as creditable, seeing that 48 per cent. of these milks would be pronounced unfit for human food in Boston, U.S.A., while in Rochester, New York, only 23 per cent. would have escaped being condemned, and Dr. Bigger has arrived at the conclusion that to allow some of the milks which he has tested to be sold for food is absolutely wrong. As regards source of supply, rail borne milks generally disclose a much higher bacterial content than the others examined, especially during the warm months, but, considering the longer interval which may be assumed to have elapsed between the milking and examination, it is not to be inferred that a markedly lower standard of care and cleanliness is adopted in country districts.

Fifty samples were tested for the presence of tubercle bacilli, and positive results were obtained in four instances. It is a disquieting

reflection to " discover that one milk out of each twelve sold in the city contains living tubercle bacilli and is capable of causing tuberculosis in the consumers, especially if these be infants or young children."

In comparison with the results of total bacterial content obtained in similar inquiries relating to the milk supplies of other large centres of population, the present investigation warrants the opinion that while in a few cities the milk has been found to be slightly worse than that of Dublin, in many it is very much superior. It should not be overlooked that Dublin possesses a great advantage over the majority of cities of equal or greater size in England and Scotland, since the most considerable part of its milk is produced in the city itself or in its immediate vicinity, and has not to be brought by rail from a distance.

It is important to recognise that " it is from cow manure, either directly or indirectly, that the majority of the bacteria found in milk come," and that accordingly " the essential requirement for the production of clean milk is to prevent the access of cow manure to it." In this connection Dr. Bigger describes an instructive experiment to test the effect of simple precautions on the purity of milk. These precautions included a thorough washing of the milk pails, cleaning of the udders, teats, belly and legs of the cow, and washing of the milker's hands and arms. As compared with milk obtained by the ordinary methods, the samples gathered under the improved procedure showed a reduction of the average number of total organisms to about one-thirtieth, while the average souring interval was extended three-fold. The last mentioned result is of great importance alike in its commercial aspect and from the point of view of the householder, and should be regarded as a set-off against the increased cost of production, which more careful methods of handling may entail.

The means by which a cleaner and more wholesome milk supply may be secured are detailed with clearness in the report, and it is within the powers of the Corporation to prescribe the necessary reforms by means of regulations made under the Contagious Diseases (Animals) Acts, 1878 and 1886. The Local Government Board have on recent and previous occasions advised the Corporation of the desirability of allocating additional staff for dairy inspection purposes and of instituting a system of bacteriological examination in reference to rail borne milk. The need for action in both these directions is emphasised by the information now placed at the disposal of the Corporation, but it is evident that the bacteriological facilities should embrace the entire milk supply of the city, whether locally produced or conveyed from outside districts.

Dr. Bigger discusses two interesting methods of improving the quality of the public milk supply, suggested by the practice and experience of other countries.

A system of grading has been adopted elsewhere, as the result of an unofficial or of administrative action, and has aimed at securing a differential marketing of milk based on quality and supported by a guarantee of production under wholesome conditions. It is primarily a matter of negotiation between milk pro-

ducers and some representative body acting on behalf of consumers, and when a standard of quality has been agreed upon, its observance can be enforced under the legislation relating to the sale of pure food. The Corporation would be well advised to take up the matter with the Dublin Dairymen's and Cowkeepers' Association, with a view to arriving at conditions for placing on the market milk of superior quality and designated with an appropriate and distinctive description. The conditions might include the systematic application of the Tuberculin test, compliance with the protective measures already indicated for the prevention of contamination, and the use of bacteriological facilities to be provided by the Corporation.

The introduction of a compulsory bacteriological standard for milk, if involving liability to penalty for non-compliance, is less capable of immediate application. At present the technical machinery authorised by law for the administration of the enactments relating to the sale of food in this country is confined to chemical analysis and does not embrace bacteriological examination. While on general grounds it would seem reasonable that the community, in regard to pure food, might be afforded the protection available from the advance of scientific research, it will be seen that at the present the establishment of an obligatory bacteriological standard applying to the sale of milk is beyond the sphere of administrative action, but is a matter for the consideration of the Legislature.

The Corporation and the citizens of Dublin are now presented with a concise and impartial review of the extent to which the city milk supply is affected by contamination. The unfavourable features are at once considerable and apparent, and it will remain for public opinion to insist that the appropriate remedies shall be applied.—I am, &c.,

A. R. Barlas, Secretary.

Dr. M. J. Russell,

Acting Medical Superintendent Officer of Health,

Public Health Committee, Dublin Corporation.

Pathological Laboratory,

Trinity College, Dublin,

5th November, 1920.

To the Local Government Board, Dublin.

Gentlemen,—I have the honour to submit the attached report on "A Bacteriological Investigation of Dublin Milks and the Pure Milk Problem."—I have, &c.,

Joseph W. Bigger.

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INTRODUCTION.

It has, of late years, been recognised that milk, as commonly collected and distributed, is contaminated with unnecessarily large numbers of bacteria. Although many of the types of micro-organisms found in milk are harmless, it has been shown that dangerous varieties may be present, and that very heavily contaminated milk, although no known pathogenic types may be found, is capable of causing serious illness in infants and young children.

For these reasons the present investigation into the bacterial content of Dublin milks was undertaken. The results of this inquiry are stated in the following report and, to provide a basis for comparison, references are made to the work of other bacteriologists who have examined the milks of several cities.

During the course of the investigation, it appeared desirable that its scope should be widened so as to include the ways in which milk acquired an undesirably large number of bacteria, and how the access of these might be prevented.

In order to make the report as complete as possible, a considerable amount of material has been collected from the published works of other investigators. This was necessary, as the greater portion of this work was published in text-books and journals which are not accessible to the general reader.

Finally the legislative and other steps, which have provided a purer milk supply in other cities, are examined and suggestions are made which are considered suitable for the needs of Irish cities.

It is hoped that this report will serve the purpose of giving a fairly comprehensive view of the bacteriology of milk in its relation to public health, and of the problem of a pure milk supply. Technical details have been reduced to a minimum in the body of the report, in order to render the reading of it possible to a layman, but the practical methods used are described in the Appendix.

PART I.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF DUBLIN MILKS.

The first part of this paper describes the results of an investigation into the numbers of various types of bacteria found in milks offered for sale in the City of Dublin.

Nature and Objects of the Tests Used.

It is impossible to produce milk which is quite free of organisms, but proper care, under suitable conditions, can prevent a large amount of the bacterial contamination to which milk is, at present, subject.

Manure always contains great numbers of bacteria, and it is from cow manure, either directly or indirectly, that the majority of the bacteria found in milk come. Under natural conditions bacteria are present, to a greater or less extent, almost everywhere, so there is always the possibility of further organisms gaining access to milk from dust and unclean vessels or by any exposure. Furthermore, milk is, in itself, a medium favourable to the rapid multiplication of bacteria, so that a milk, produced under conditions of the greatest cleanliness will, if kept for a comparatively short time at too high a temperature, come to contain a larger number of bacteria than one, to the collection of which less attention was given, but which had been kept at a low temperature.

In an examination of a considerable number of commercial milks, such as that described in this paper, we find ourselves dealing with four unknown factors :—

1. The original contamination at the place of milking.
2. Subsequent contamination during transport and distribution.
3. The time elapsing between milking and the examination of the milk.
4. The temperature at which the milk was kept.

We can discover the total number of organisms contained in the milk which are capable of growing under certain conditions, and the numbers of certain types of these. The temperature of the milk at the time of its examination is easily found and, by taking care always to obtain samples at about the same time of day, and therefore probably of about the same age, some control of factor number 3 can be exercised.

As regards the different methods of contamination, the various examinations carried out are capable of giving some, although a limited amount, of information.

Total Bacteria.

First the organisms capable of growing on trypagar at body temperature (37.5°C.) were enumerated. The figures obtained in this way do not represent the total number of living bacteria in the milk, for by no method is it possible to count all of them. Many

bacteria commonly found in the air or on vegetation may gain entry to milk, but they, for the most part, are only adapted for growth at a much lower temperature than that of the body, and so will not reveal their presence when cultures of milk are grown at the higher temperature.

On the other hand, a large number of the bacteria which live normally on, or in, the bodies of man or of other animals, either harmlessly or harmfully, will grow best, or will only grow, at or near the body temperature, and this method of culture will show their presence. There is a strong presumption that any organism found in these countries which grows vigorously at 37.5°C. was originally derived from, or is capable of living in, the body of some animal. While this presumption does not entitle us to assume that all such organisms would act harmfully if introduced into our own bodies, we know that most of the other organisms present in milk which do not grow at higher temperatures would certainly be harmless if taken into our systems.

For these reasons, the total organisms counted were those capable of growth at 37.5°C., and not those growing at 20° to 22°C.

Lactose Fermenting Bacilli.

The number of bacilli which do not retain the stain by Gram's method, and which ferment the sugar lactose, producing both acid and gas, were enumerated for each milk. These organisms are almost entirely derived from faecal matter, being absent from material never contaminated with animal excreta. Since, from the nature of the place of origin of cow's milk, cow's dung is the chief likely source of these organisms, their number in a milk gives us an indication of the amount of cow's manure which has been permitted to come in contact with the milk. For this reason they are called "Indicator organisms." The chief members of the group found in milk are B. coli, B. lactis aerogenes and B. acidi lactici, all of which are of considerable importance in the souring of milk.

Streptococci.

Streptococci have been enumerated because they are also, to some extent, indicators of manurial contamination. They are not, however, so useful for this purpose as the last group, for, although they are present apparently as harmless parasites in cow's dung, as in other faeces, they are frequently found in the milk of healthy cows, obtained under ideally clean conditions, and also in various diseases, both of the cow and of man. Since their source is more variable, the value of their count is therefore probably less than that of the lactose fermenting bacilli.

Spores of B. Enteritidis Sporogenes and other Anaerobic Bacteria.

Spores of certain anaerobic bacilli (B. enteritidis sporogenes and B. butyricus) were also counted. Their source is almost certainly manure, but, on account of their power of resisting adverse conditions, they may be found in dust, hay, straw and many other materials. Probably those found in milk are derived mainly from

cow manure. Since they are incapable of developing in milk, under natural conditions, their number should be an indication of the manurial contamination alone, as it is independent of the age of the milk and of the temperature at which it was kept.

Tubercle Bacilli.

A number of milks were tested for the presence of tubercle bacilli, but no attempt was made to count these. They are derived from cows suffering from tuberculosis, and may be present in the milk as it comes from the cow (chiefly, but not entirely, when the udder is affected), or may be added to the milk by the addition of manure which, if from a tuberculous cow, may contain large numbers of tubercle bacilli.

The bovine type is less virulent for man than the human type of the bacillus, but it is the cause of a large percentage of the gland, bone and abdominal tubercular disease of children.

Methods of Obtaining Milks for Examination.

Between August, 1919, and July, 1920, one hundred milks were examined with respect to the total organisms, lactose fermenting bacilli, streptococci, and spores of B. enteritidis sporogenes and kindred organisms.

The milks were purchased for me by one of the Food Inspectors of the Dublin Corporation in shops or from carts in the City of Dublin. The milks are therefore those used by the inhabitants of the city and are in no sense selected, samples having been taken in all parts of the city.

The samples were taken into sterile bottles which were at once brought to the laboratory, where the temperature was taken and the examination carried out. Samples were always taken in the morning, usually between 9.30 and 11 a.m., and therefore the milk should generally have come from the cow on the same morning. The interval between the purchase of the milk and its examination was as short as possible and never exceeded two hours. In the majority of cases the interval was less than one hour.

Results.

Milks were examined in every month of the year, except in March and April. The table in Appendix I. shows the results obtained for the hundred milks, and also in which ward of the city the milk was purchased, and the source from which the seller had obtained it. In many cases, however, it is to be feared that this information does not give the ultimate source of the milk, since a considerable amount of milk enters the city consigned to dealers who distribute it to retail shops. In such cases the place of origin of the milk is unknown to the seller. The temperature of each milk when it was brought to the laboratory is also recorded.

In Appendix II. the details of the methods of examination used are given.

Differences between Winter and Summer Milk.

The first fact which may be noted in examining this table of results is the very wide differences in the numbers of organisms

contained in different milks, even in milks examined in the same month. In the month of January, for example, the best milk contained 32,000 organisms per cubic centimetre,* and the worst 5,360,000. Apart from this, however, there is, in general, a considerable tendency for the figures to be higher in the warmer months of the year than in the cooler.

This seasonal variation is demonstrated in the following table, which gives the average figures for the winter months of January, February, November and December, and for the summer months, May till October. 51 milks were examined in the four winter months and 49 in the six summer months. In order to exclude the exceptional milks (either unusually good or unusually bad), the averages have been struck after the three best and three worst milks examined in each period were excluded from consideration.

TABLE I.

AVERAGE FIGURES FOR WINTER AND SUMMER MILKS.

Season.	Temperature °C.	Total Bacteria per c.c.	Lactose fermenters per c.c.	Streptococci per c.c.	Spores in 20 c.c.
Winter ..	11·7	627,000	739	132,000	2·2
Summer ..	17·7	4,183,000	13,284	309,000	1·7

The summer average for total organisms is nearly seven times that of the winter. For lactose fermenters the summer figure is about eighteen times that of the winter. The streptococci figures vary much less, the summer being only about two and a half times that of the winter.

Results for Milks Examined in each Month.

In order to show the results, month by month, the following four tables have been constructed. They show the numbers of total organisms—lactose fermenting bacilli, streptococci and spores—in the best and worst milk examined in each month, and also the average figure of all the milks examined in the month. It has been found very difficult to devise a method of arriving at an average for these tables, since the number of milks examined in any month has been small. A crude average would give a totally wrong impression, as can be understood by examining the figures for the month of May. The crude average for the total organisms in the milks of that month is 4,193,000, a figure only exceeded by two milks examined in the month, and accounted for by one abnormally bad milk (No. 26), with a total count of 28,800,000 bacteria per c.c. A fairly satisfactory method would have been to exclude from the calculation one or two of the highest and lowest figures. It was felt, however, that this method was somewhat arbitrary and might allow personal bias to affect the results. Moreover, it

* A cubic centimetre (c.c.) contains about 20 drops.

seemed desirable that even an unusually bad milk ought to have some weight in deciding the result. The following method was therefore devised, and all the figures shown in the four tables are calculated by it. The figures for the month were arranged in order of magnitude and their average taken (*a*). The highest and lowest were excluded and the average of the remainder (*b*) was struck. Again the highest and lowest were excluded and a further average made (*c*). This process was repeated until all the figures had been excluded in turn and a number of averages obtained. The sum of these divided by their number gave the final average, the " average of averages."

TABLE 2.

TOTAL ORGANISMS PER CUBIC CENTIMETRE.

Month.	Temperature of Milk (°C.)	Highest.	Lowest.	Average.
January, 1920	11·6	5,360,000	32,000	373,000
February ,,	11·0	3,140,000	56,000	425,000
March, ,,	—	—	—	—
April, ,,	—	—	—	—
May, ,,	18·6	28,800,000	64,000	1,876,000
June, ,,	17·9	13,200,000	28,000	1,559,000
July, ,,	18·9	27,800,000	132,000	4,102,000
August, 1919	19·1	73,200,000	700,000	10,185,000
September, ,,	17·1	10,200,000	100,000	2,361,000
October, ,,	14·4	14,800,000	24,000	1,572,000
November, ,,	12·1	9,600,000	12,200	678,000
December, ,,	11·9	3,220,000	22,000	289,000

The highest result obtained was in August (73,200,000 per c.c.) and the lowest in November (12,200 per c.c.). The lowest average figure was for December, from which there was each month, with the exception of June, an increase up to the highest in August, followed by a steady fall back to the December average.

TABLE 3.

LACTOSE FERMENTING BACILLI PER CUBIC CENTIMETRE.

Month.	Highest.	Lowest.	Average.
January ..	5,000	10	285
February ..	5,000	10	434
May ..	25,000	10	939
June ..	10,000	10	703
July ..	100,000	10	4,064
August ..	250,000	50	33,300
September ..	250,000	50	25,731
October ..	250,000	50	8,417
November ..	100,000	5	1,266
December ..	50,000	10	893

The months of August, September and October each furnished figures of 250,000 lactose fermenters per c.c. The lowest figure (5) was found in the month of November. The lowest average was for January, from which there was a steady rise (again excepting June) to August, after which the average fell to the January level.

TABLE 4.

STREPTOCOCCI PER CUBIC CENTIMETRE.

Month.	Highest.	Lowest.	Average.
January ..	500,000	1,000	58,000
February ..	500,000	5,000	33,000
May ..	500,000	10,000	98,000
June ..	1,000,000	10,000	154,000
July ..	1,000,000	50,000	418,000
August ..	1,000,000	10,000	525,000
September ..	1,000,000	10,000	509,000
October ..	1,000,000	1,000	111,000
November ..	1,000,000	1,000	157,000
December ..	1,000,000	1,000	68,000

The maximum figure of 1,000,000 streptococci per c.c. was recorded in seven, and the minimum of 1,000 in four out of the ten months. The average for February was the lowest and for August the highest in the year.

TABLE 5.

SPORES OF ANÆROBIC, GAS-FORMING BACILLI IN 20 CUBIC CENTIMETRES.

Month.	Highest.	Lowest.	Average.
January ..	10	0	1·7
February ..	6	1	2·4
May ..	10	0	2·2
June ..	4	0	0·8
July ..	3	0	1·1
August ..	9	1	1·9
September ..	4	0	2·0
October ..	6	0	2·1
November ..	8	0	2·2
December ..	4	0	1·4

These figures do not seem to be sufficient to warrant any conclusions as to seasonal variation.

These tables and Charts 1 to 3, which illustrate them, can leave no doubt of the importance of the time of year as a factor in the bacterial contamination of milk. Nevertheless, good results are met with during the summer and bad ones in cold weather. It therefore appears desirable to show the bacteriological classification of the milks of each month.

Classification of Milks Examined.

The following table divides milks into five classes, A, B, C, D, and E, according to the total number of organisms found in each cubic centimetre.

TABLE 6.

CLASSIFICATION ACCORDING TO TOTAL ORGANISMS IN EACH CUBIC CENTIMETRE.

Month.	Number examined.	A. Under 30,000	B. 30,000 to 100,000	C. 100,000 to 500,000	D. 500,000 to 1,000,000	E. More than 1,000,000
January ...	14	0	4	7	1	2
February ...	8	0	2	2	3	1
November ...	18	2	5	4	2	5
December ...	11	2	1	6	0	2
WINTER ...	51	4	12	19	6	10
May ...	10	0	2	1	2	5
June ...	9	1	1	2	2	3
July ...	8	0	0	3	0	5
August ...	9	0	0	0	2	7
September	5	0	1	1	0	3
October ...	8	1	1	3	1	2
SUMMER ...	49	2	5	10	7	25
TOTAL ...	100	6	17	29	13	35

TABLE 7.

CLASSIFICATION ACCORDING TO NUMBERS OF LACTOSE FERMENTING BACILLI IN EACH CUBIC CENTIMETRE.

Month.	Number examined.	A. Under 10	B. 10 to 100	C. 100 to 1,000	D. More than 1,000
January ..	14	1	7	5	1
February ..	8	1	4	2	1
November ..	18	3	7	5	3
December ..	11	1	6	3	1
Winter ..	51	6	24	15	6
May ..	10	1	3	5	1
June ..	9	1	1	6	1
July ..	8	1	2	3	2
August ..	9	0	1	2	6
September ..	5	0	1	2	2
October ..	8	0	2	4	2
Summer ..	49	3	10	22	14
TOTAL ..	100	9	34	37	20

The significance of these figures will be discussed later, but it may be remarked here that 48 per cent. of these milks would be pronounced unfit for human food in Boston, U.S.A., while in Rochester, New York, only 23 per cent. would have escaped being condemned.

Effect of the Source of the Milk on its Bacterial Content.

As previously explained, it was not always easy to trace the original source of the milk examined. In only twelve of the hundred milks is it known that the milk reached the city by rail. The results recorded for these twelve specimens will now be considered and compared with those of milks produced in the city or surrounding parts. Seven of these milks were carried by the Dublin and South Eastern Railway Co., four by the Great Northern Railway Co., and one by the Great Southern and Western Railway Co.

In the months of February, September, October and December 8 rail borne milks were examined and 24 others. In each of these four months the worst milk was one which had come to Dublin by rail.

In August two rail milks were examined, and one of them was the second worst in the month.

In November two rail milks were tested and found to contain very much fewer organisms than the average of all milks for the month.

The comparison of rail milks with others may be most clearly shown in a table. The number represents the position which the milk would occupy if all the milks examined in the month were arranged in the order of total bacterial contamination, the lowest being placed first.

TABLE 8.

POSITION OF RAILWAY MILKS IN EACH MONTH.

Number.	Month.	Position of Milk.	Worst Milk in month.
18	February ..	8	8
19	,, ..	6	8
21	,, ..	4	8
50	August ..	8	9
53	,, ..	7	9
59	September ..	5	5
62	,, ..	2	5
64	October ..	8	8
66	,, ..	3	8
79	November ..	4	18
86	,, ..	6	18
93	December ..	11	11

It will be observed that, with the solitary exception of the month of November, the rail borne milks generally show a much higher

bacterial content than the others examined. This fact does not entitle us to assume that the methods of obtaining these milks were worse than those used in Dublin and district, since probably all the milks coming to Dublin by rail were considerably older than the rest. Most of them came from the cow on the day preceding their examination, whereas the majority of the milks produced in or around the city were examined on the same day that the cows were milked. This would be sufficient to explain the fact that the rail borne milks appeared to be very bad in the warm months, but fairly good in the colder parts of the year.

Tubercle Bacilli.

Between November, 1919, and August, 1920, fifty milks were examined, by animal inoculation, for the presence of tubercle bacilli. Out of this number, four (8 per cent.) were found to cause tuberculosis in the inoculated animal. The source of these four (as stated by the seller) was the City of Dublin.

The number of milks examined is regrettably small, owing to the present great difficulty in obtaining guinea-pigs.

It is not pleasant to discover that one milk out of each twelve sold in the city contains living tubercle bacilli, and is capable of causing tuberculosis in the consumers, especially if these be infants or young children.

PART II.

THE RESULTS OF THE PRESENT INVESTIGATION COMPARED WITH THOSE OF OTHER WORKERS.

It is not always easy to compare the results of observers who have, from time to time, investigated the bacterial content of milk in different cities. Different methods of culture may cause wide divergence in the results, and it is sometimes impossible to discover, from the published papers, the season of the year at which the milks were examined and their probable age.

Previous Dublin Investigation.

Houston (1), who investigated Dublin milks in the year 1917, gives the figures for the total organisms in 77 of these examined during the summer. The best milk contained 20,000, and the worst 83,000,000 bacteria in each cubic centimetre. The average number per cubic centimetre, excluding the three best and the three worst, was 12,360,000. The fact that this is considerably higher than the average bacterial content of milks examined during the summer in the present investigation (4,183,000) is probably due to the difference in the average temperature in the summers, differences in the ages of the milks, and the use of different cultural methods.

New York.

Park (2) found in New York, before the campaign for clean milk had begun, that the average bacterial content of store milk in each

cubic centimetre was 300,000 in the coldest weather, 1,000,000 when the weather was cool, and 5,000,000 when hot.

A more recent investigator of New York milks, Schroeder (3) found that 83 per cent. contained less than 100,000 bacteria per cubic centimetre. The wide difference between the results of these two workers shows to what a great extent the milk of a city is subject to improvement, if such improvement is insisted upon both by the health authorities and by the general public.

London.

Hewlett and Barton (4) found that the numbers of bacteria in each cubic centimetre of milk sampled at London railway termini varied from 20,000 to 8,390,000, with an average of about 1,500,000.

Williams (5) gives figures, obtained by workers at the Lister Institute, who examined, during the summer, 26 milks which were being used by Infant Welfare Centres. The worst milk contained 65,400,000 and the best 98,000 bacteria in each cubic centimetre, the average figure, excluding the three best and three worst, being 4,075,000.

Edinburgh.

Cunningham and Thorpe (6) have recently published the results of their bacteriological investigation of Edinburgh milk. Forty milks were examined during the winter, and the numbers of bacteria were found to vary between 500 and 26,000,000 in each cubic centimetre. The average, excluding the three highest and three lowest, was 790,000 bacteria per cubic centimetre—a figure very close to that obtained during the winter months in the present investigation. The percentage of winter milks which did not contain over 500,000 bacteria in each cubic centimetre was practically the same both in Edinburgh and Dublin—70 per cent. in the former and 69 per cent. in the latter.

The numbers of lactose fermenters per cubic centimetre in the Edinburgh milks varied from 0 to 10,000, and the average, found as before, was 193—about one-quarter of the winter average found by the present writer in Dublin milk. 50 per cent. of the Edinburgh milks contained not more than 10 lactose fermenters in each cubic centimetre, while in less than 12 per cent. of the Dublin winter milks did the number of these bacteria fall below that figure.

We see, therefore, that while the total number of bacteria in Edinburgh and Dublin milks is about the same, the former contains fewer lactose fermenters and is, on this account, probably less contaminated with manure than that of Dublin.

Further figures relative to the numbers of bacteria in the milks of various cities might be given, but the value of such comparisons, where the details of the investigation are different, is limited. The

conclusion of the present writer, after an examination of a considerable number of other investigators' results, is that while, in a few cities, the milk has been found to be slightly worse than that of Dublin, in many it is very much superior. In this connection it should be realised that Dublin possesses a great advantage over the majority of cities of an equal or greater size in England and Scotland, since the most considerable part of its milk is produced in the city itself, or in its immediate vicinity, and has not to be brought by rail from a distance. For this reason it is possible to obtain, in Dublin, milk which has come from the cow only a few hours before. Most London milk is, at least, twenty-four hours old before it is purchased by the consumer.

The milk of Dublin should be markedly superior to that of London or of other English cities, and, since it does not appear to be so, there is something wrong in its methods of production or distribution. Methods which help to improve the bacteriological quality of milk will be discussed in Part IV. If these were carried out, the milk supply of Dublin would be second to that of no city in the world.

Tubercle Bacilli.

The proportion of the milks of various cities and towns found to contain tubercle bacilli can be most clearly seen when the figures are arranged in tabular form. The following table gives the results of some of these examinations.

TABLE 9.

TUBERCLE BACILLI IN MILK.

Place.	Date.	Authority.	Milks examined	Positive	Per Cent.
Cambridge	1899	Kanthack and Sladen (7).	16	9	56·2
Berlin ...	1899	Petri (8) ...	–	–	14
Berlin ...	1900	Beck (8) ...	–	–	30·3
Washington	1908	Anderson (9) ...	102	11	10·7
New York	1908	Hess (10) ...	107	17	16
Leipzig ...	1908	Eber (8) ...	–	–	10·5
Philadelphia	1909	Campbell (11) ...	123	18	13·8
Wakefield ...	1910	Savage (12) ...	28	4	14·3
Manchester	1897-1913	Delépine (13) ...	7,681	671	8·7
London ...	1907-1913	Medical Officer, L.C.C. (14).	13,321	1,323	9·9
Do. ...	1913	do. ...	2,682	251	9·3
New York	1912-1913	Grund and Wilcox (15).	–	–	11·5
Edinburgh	1913-1914	Mitchell (16*a*) ...	406	82	20
London ...	–	Barton and Hewlett (4).	25	1	4
Dublin ...	1919-1920	Bigger ...	50	4	8

The figures given in the next table have been taken from " Milk and the Public Health," by Savage.

TABLE 10.

TUBERCLE BACILLI IN MIXED MILK SAMPLES (PERCENTAGES).

——	1907.	1908.	1909.	1910.
Liverpool—Country Samples	4·7	3·3	1·8	4·1
Liverpool—Town Samples	1·5	2·0	0	1·4
Sheffield—Country Samples	9·7	9·9	10·9	10·4
Birmingham „ „ ..	–	11·3	7·5	7·3
Leeds „ „ ..	–	25·3	16·4	–
Sunderland	2·5	7·0	7·4	3·6

Fifty milks is a rather small number from which to draw any conclusions, but, if a larger number, five hundred for example, had been examined, and the same percentage of positive results found, it might be concluded that, although the percentage was far too high, yet it was lower than that of many cities. This conclusion should give us no grounds for self-congratulation, for, whatever the true percentage as found by the examination of a very much larger number of milks might be, the present investigator has found four tubercular milks in a batch of fifty offered for sale in the city. There is, in this, room for a very great improvement.

PART III.

DANGERS OF CONTAMINATED MILK.

As has already been explained, the greater number of the bacteria found in milk are harmless to man. Milk, however, becomes dangerous if it contains bacteria which cause disease. Such organisms may be derived from the cow or from persons who have dealt with the milk at any stage between the cow and the consumer, and who are suffering from, or are carriers of the organisms of, an infectious disease.

Disease Derived from the Cow.

The most common disease of the cow which is communicable to man is tuberculosis. The question of the relation of this disease in cattle and in man will be dealt with in some detail later.

It is well established that some epidemics of sore throats have been due to a streptococcus which was present in the milk of cows suffering from inflammation of the udder or from ulcerated teats. Any sign of ill-health or, more particularly, of disease of the milk apparatus in a cow, should be sufficient immediately to prevent the milk of the animal being used as food, certainly in its raw state.

Milk-borne Epidemics.

The chief of the infectious diseases which are spread by milk are the enteric group of fevers, scarlet fever and diphtheria. Schüder (17) analysed 650 epidemics of typhoid fever, and found that the

chief source of infection in 110 of these was milk. Park and Williams (18) give the following as the number of epidemics and cases of four diseases which have been traced to infection by milk :—

Typhoid Fever	...	179	epidemics	with 6,900	cases.
Scarlet Fever	...	51	,,	,, 2,400	,,
Sore Throat	...	7	,,	,, 1,100	,,
Diphtheria	...	23	,,	,, 960	,,

These are probably only a small proportion of the totals due to infected milk. Apart from the few and inconclusive cases of scarlet fever and diphtheria in which it was alleged that lesions on the teats of cows were the cause of the disease in man, these epidemics are due to someone suffering from the disease in question, or still carrying the causative organism, who, at some stage of its collection or distribution, had access to the milk. It is obvious that the less chance that dirt has of entering the milk, the less risk is there of infection. If, for example, covered cans are used and the milker's hands are well washed, the risk of infective material from him entering the milk is greatly lessened. Similarly if the milk is properly protected at every stage up to and including its distribution, there is a decreased chance of infective persons conveying infection to the milk. Most commonly, carriers of disease bacteria are ignorant of the fact that they are a source of danger to others.

Milk and Infantile Diarrhœa.

Milk is essentially the food of infants and young children, and one of the commonest causes of illness and death of these is the severe epidemic diarrhœa, so prevalent in the summer and autumn months, especially when the summer is a very warm one. It is rather humiliating to a bacteriologist to have to confess that the cause of this disease is still unknown. We do know, however, that breast-fed infants escape very much more lightly than those who are bottle fed, and, of the children who are fed from a bottle, those using dried milk or a patent food are, in general, less affected than those using cow's milk. The disease is rare among children of the well-to-do classes, but is all too common in those who live in slums or tenement houses. There is no doubt that it is a " dirt " disease, for where there are dirt and flies the disease is almost certain to appear during the hot weather. Various bacteria have been, at one time or another, accused of being the cause of epidemic diarrhœa, but against none has a conclusive case been made. While we cannot, therefore, attach blame to one organism, there is no doubt that in dirty milk the cause is to be found : the more heavily a milk is contaminated, the more likely is the disease to develop. But, since pasteurisation of a grossly contaminated milk lessens but does not entirely destroy, its dangerous qualities, it appears probable that the disease is due, not so much to living bacteria, as to some poisonous substance produced in milk by the growth of one or more types of micro-organism. The initial irritation of the

alimentary canal is, most likely, due to the effect of this poison, but the later stages are almost certainly to be ascribed to the agency of bacteria, possibly of types which are innocuous to the healthy intestine. That living bacteria play an important part, if not the initial one, is, I believe, certain.

Park and Williams (18) give the following table, which shows the effect on infants of two types of feeding :—

TABLE 11.

THE EFFECT OF FEEDING INFANTS WITH RAW AND PASTEURISED MILK.

Kind of Milk.	Number of Infants.	Remained well for Summer.	Number with Diarrhœa.	Average days off Milk during Summer	Average weekly gain in weight.	Average number of days Diarrhœa.	Deaths
Pasteurised, 1,000 to 50,000 bacteria per c.c	41	31	10	3	4·0 ozs.	3·9	1
Raw, 1,200,000 to 20,000,000 bacteria per c.c. ...	51*	17	33	5·5	3·5 ozs.	11·5	2

* Thirteen of these were transferred, before the end of the trial, to pasteurised milk because of serious illness. If these infants had been left on raw milk, it is believed by the writers that the comparative results would have been even more unfavourable to raw milk.

This table shows that infants fed on pasteurised milk are much less liable to diarrhœa than are those fed on dirty raw milk.

The conclusions of Park, Williams, and Holt on the results of feeding 112 infants and 47 children aged between one and two years on various types of milk will be given in some detail :—

"1. During the cool weather neither the mortality nor the health of the infants observed in the investigation was appreciably affected by the quality of the market milk or by the number of bacteria which it contained. The different grades of milk varied much less in the amount of bacterial contamination in winter than in summer, the store milk averaging only about 750,000 bacteria per cubic centimetre.

"2. During the hot weather, when the resistance of the children was lowered, the kind of milk taken influenced both the amount of illness and the mortality: those who took condensed milk and cheap store milk did the worst, and those who received breast milk, pure bottled milk and modified milk did the best. The effect of bacterial contamination was very marked when the milk was taken without previous heating: but, unless the contamination was very excessive, only slight when heating was employed shortly before feeding.

"3. The number of bacteria which may accumulate before milk becomes noticeably harmful to the average infant in summer differs with the nature of the bacteria present, the age of the milk, and the temperature at which it has been kept. When the milk is taken raw, the fewer the bacteria present the better are the results. Of the usual varieties, over 1,000,000 bacteria per cubic centimetre

are certainly deleterious to the average infant. However, many infants take milk without apparently harmful results. Heat of 145°F. for thirty minutes, or of 170°F. for a shorter period, not only destroys most of the bacteria present, but apparently some of their poisonous products. No harm from the bacteria previously existing in recently heated milk was noticed in these observations, unless they had amounted to many millions, but in such numbers they were decidedly deleterious."

The conclusions of these authorities, who have studied the relation between milk and infantile diarrhœa very thoroughly, cannot fail to carry weight, and whether it be decided better to feed an infant whom his mother cannot suckle on raw or on heated milk there can remain no doubt of the necessity of obtaining that milk as free from bacteria as possible.

Bacteria, by their growth on milk, not only add to the milk substances, about the nature and effects of which we know little, but also take from it some of the material which renders it an especially valuable food for the young and alters it into something which may actually be harmful.

Milk and Tubercle Bacilli.

There are two main types of tubercle bacilli—the human and the bovine. The former may occasionally be present in milk, but the latter, derived from cattle, are much more common.

The sources of tubercle bacilli in milk are:—

1. Milk of a cow suffering from tuberculosis of the udder.
2. Milk of a cow suffering from tuberculosis of some other part.
3. From the faeces of a cow suffering from tuberculosis of the lung or alimentary canal.

Tuberculosis in cattle is probably even more common than in man. Savage (8) estimated that 25 to 30 per cent. of cows are tubercular, and that 2 per cent. of all cows in England have tuberculous udders, while McFadyean (8) puts the latter condition at between 2 and 3 per cent. Buckley (19) states that 10 per cent. of heifers with their first calf react to tuberculin, but a much higher percentage of older animals. Where tuberculosis of the udder is present enormous numbers of tubercle bacilli pass into the milk. Delépine (8) found that milk from a cow with advanced udder tuberculosis caused that disease in a guinea-pig when so small a quantity as 0.002 c.c. was inoculated into it. It will, therefore, be seen that even one tuberculous cow can render infective the milk of a whole herd.

That tubercle bacilli may be present in the milk of a cow in which no lesion can be detected, either clinically or at *post-mortem* examination, in the udder has been amply demonstrated. The Royal Commission on Tuberculosis (20) had *post-mortem* examinations made on three cows the milk of which contained tubercle bacilli but in the udders of which no lesion could be detected clinically. In two of these the *post-mortem* examination failed to show any udder disease, and in one four small nodules were found in one quarter of the udder.

Rabinowitch and Kempner (8) examined the milks of 14 cows which reacted to tuberculin but only one of which exhibited any clinical signs of udder disease. Tubercle bacilli were present in the milks of ten of these.

That the dung of tuberculous cattle contains tubercle bacilli is proved by an investigation of the Royal Commission (20). Out of six cows which were suffering from natural tuberculosis, and which reacted to tuberculin, only three showed signs of tuberculosis clinically, but the faeces of five contained tubercle bacilli.

It follows naturally that the cleaner the milking conditions are, and the better the precautions taken to prevent the access of cow dung to the milk, the less risk will there be of that milk containing tubercle bacilli derived from faeces.

The above evidence is sufficient to prove the prevalence of tuberculosis among dairy cows and the possibilities of milk being rendered infective with tubercle bacilli. A marked tuberculosis of the udder is fairly obvious, even to the most superficial observer, but early udder lesions, or the disease in other parts of the body, which are almost as dangerous to man, are not so easily diagnosed clinically. Fortunately we have in tuberculin a very valuable diagnostic agent. Its use has not been so common in Ireland as it should be. Many have either refused to believe in its results or have argued that a reaction with it may indicate a very small lesion which is of no importance. Such a lesion is, however, of importance, for it is very likely that the disease will spread throughout the cow's body from the original focus of infection. Tuberculin should only be used by a qualified veterinary surgeon experienced in the proper method of applying the test. Nocard (21) states on the subject of the reliability of the tuberculin test:—" Speaking for myself, I have up to now personally and publicly performed 500 autopsies of animals which had reacted to tuberculin. In only three cases have I failed to find the lesion sought for." Further evidence is supplied by Buckley (19), whose herd consists of 100 milch cows. Every cow is tested with tuberculin on its arrival, and only those which do not react are retained. They are again tested at the end of three months and subsequently every year. Since 1907, 688 tests were made. Only two cows reacted at the second test and none subsequently. This also shows that it is possible to form a herd of non-tubercular cows and to keep it free from tuberculosis.

A tubercular cow in a herd is a danger, not only to man, but also to other cattle. Sooner or later a cow which reacts to tuberculin will start to excrete tubercle bacilli in her milk and faeces, and so will infect, by the former, her own or other calves and, by the latter, other cattle. Tubercle bacilli remain alive for at least several months in cow dung on grass.

The Amount of Tuberculosis Due to the Bovine Type of Tubercle Bacillus.

There is a very great body of evidence as to the prevalence of the bovine type of tubercle bacilli in human tuberculosis, especially that of children.

Lewis (22) from 15 consecutive cases of tubercular cervical adenitis obtained the bovine type of bacillus in 9 and the human in 6.

Park and Krumwiede (23), in 1910, analysed their own results and those of 17 other investigators, considering 1,042 cases of all types of tuberculosis in man. The percentages due to the bovine type were: in adults, 1.3 per cent. or, excluding phthisis, 7.3 per cent.; in children from 5 to 16 years old, 25.0 per cent.; in children under 5 years, 26.7 per cent. In cervical adenitis, 61.0 per cent. of the cases under 5 years and 38.0 per cent. of those between the ages of 5 and 16 years were due to the bovine type. In abdominal tuberculosis 58.0 per cent. under 5 years and 53.0 per cent. between 5 and 16 years were due to the bovine bacillus.

Mitchell (16b), in 1915, from 80 consecutive cases of tubercular cervical glands in children living in Edinburgh and district isolated the bovine type in 88 per cent.

Eastwood and Griffith (24), in 1916, analysed 261 cases of human bone and joint tuberculosis and found that 21.1 per cent. of cases at all ages, were due to the bovine type of bacillus. Below 10 years the bovine infections were 29.0 per cent. of the whole, and at ages over 10 years, 9.4 per cent.

Griffith (25) found bovine tubercle bacilli in 72 per cent. of cases of tubercular glands in children under ten years of age.

This mass of evidence is fairly summed up in the words of the Royal Commission on Tuberculosis (26):—" There can be no doubt but that in a certain number of cases the tuberculosis occurring in the human subject, especially in children, is the direct result of the introduction into the human body of the bacillus of bovine tuberculosis; and there also can be no doubt that, in the majority at least of these cases, the bacillus is introduced through cow's milk. Cow's milk containing bovine tubercle bacilli is clearly a cause of tuberculosis and of fatal tuberculosis in man."

In order then to have milk which does not contain specific disease bacteria we require:—

1. Healthy cows.
2. Healthy workers.
3. Clean conditions.

PART IV.

INVESTIGATION OF THE FACTORS IN THE CAUSATION OF DIRTY MILK AND HOW THESE MAY BE AVOIDED.

The first part of this paper gave the results of an examination of a number of milks sold in Dublin, and explained that the three important factors in causing milk to contain large numbers of bacteria were:—

1. Contamination, chiefly with cow dung.
2. Temperature.
3. Time.

The present part will deal with these factors in greater detail, for it is necessary to render as definite as possible our knowledge of the causes of any unsatisfactory condition before attempting to remedy it.

It is generally conceded that the first of the three factors, given above, is the most important from the point of view of public health and that it is the one most difficult to remedy. If the time which elapses between the collection of milk and its use must, of necessity, be long, its evils may be lessened by keeping the milk cold, while, if it is impossible to cool the milk satisfactorily, its high temperature may be made of little effect by using the milk very soon after its collection. Further, the greater the number of bacteria gaining access to the milk, the greater is the chance of some of these being varieties which may be harmful to the consumer.

For these reasons the methods of milking in common use in Ireland to-day may be considered in some detail.

Milking Methods.

A person educated in the principles of bacteriological cleanliness, or even one who, ignorant of bacteriology, has nice feelings about cleanliness in general, can hardly fail to be disgusted at the present-day methods of milking. Necessarily the association between milk and cow manure must be close, but close association is very different from actual contact, although, in the usual milking shed, the two appear to be synonymous. The milking pail is frequently imperfectly washed, perhaps merely rinsed in cold water. The milker's hands are unwashed or, if perfunctorily washed, have been subsequently used for tying up the cows, slapping their flanks to get them into position, and holding a filthy milking stool. The cows may be groomed occasionally, but this is generally done before selling and not before milking. It is very rare to find that the teats and udder have been washed, or even rubbed with a damp cloth. The pail has been left uncovered, lying frequently in a place contaminated with manure, until the cows are ready. Then the man takes it between his manure-laden legs and gets to work. In order to moisten his hands he allows a jet of milk to flow over them. Subsequently, to obtain further moisture, the easier and commoner method is to dip the fingers into the milk pail. It is almost impossible to persuade the average milker that it is unnecessary to moisten the hand in order to milk satisfactorily. The present writer does not feel competent to decide this point, as he has no experience of milking, but will content himself with what Buckley (19), a practical farmer, has written:—" Wet or even damp milking is a bad habit "; and again, " Many milkers contend that it must be performed with a wet hand; but this is untrue, and is an argument used by those who, for one reason or another, do not wish to milk ' dry.' An absolutely dry hand is best, and, with a good milker, it is as easy to milk in this way as with a damp or wet hand."

Bacteria in Cow Manure.

It is unnecessary to proceed further with the description of the typical milking routine. Suffice it to say that, at almost every stage, cow manure may be introduced, directly or indirectly, into the milk.

The essential requirement for the production of clean milk is to prevent the access of cow manure to it. In order to show the importance of this some cow manure was examined. One sample of fresh dung contained 3,400,000 bacteria with 1,000,000 lactose fermenting bacilli, and another 2,200,000 bacteria with 500,000 lactose fermenters per gramme. One gramme of old, dried manure which was adherent to the leg of a cow contained 426,000,000 organisms of which 10,000,000 were lactose fermenters. This amount would have fitted on the surface of a sixpenny piece, and if added to the milk of one cow would have introduced 47,000 bacteria per cubic centimetre of the milk.

Investigation at a Farm.—Old Methods.

In order to study the bacterial content of absolutely fresh milk, which had been obtained in the usual way, and what measures were necessary to produce a cleaner milk, a temporary laboratory was established at a small farm. The milking procedure need not be described in detail; it was probably somewhat better than the average. The milker was provided with an overall, but no attempt was made to clean the udder or teats of the cow, and the milk was collected in pails, with wide tops, which were not provided with covers. The milk of the same cow, which was in a field during the day and night and was brought into a shed to be milked, was dealt with throughout the course of the investigation, which lasted for nine days. The milk obtained at nine consecutive milkings (morning and evening), under the usual conditions, was sampled and examined within ten minutes of the termination of milking.

After this various improvements were instituted, and I personally superintended the milking, which was done by the same milker as in the first series.

New Methods.

The improvements were not intended to be ideal, but were such as could be carried out with the apparatus in ordinary use.

1. The pails were rinsed in cold water, well scrubbed with a small brush, Gospo and hot water. They were again rinsed with clean cold water, and finally scalded with really boiling water. They were covered with muslin covers, which had been boiled before use. The covers were left on the pails till everything was ready for milking.
2. The long hairs about the udder were clipped.
3. The cow was brought into the milking shed and tied up. The teats and udder were washed with warm water, using a soft sponge and soap, and were dried with a clean cloth. The belly and insides of the legs were rubbed over with a damp cloth. The tail was tied back.

4. The milker arranged the stool in position and put on a clean apron. Then he rolled up his sleeves, scrubbed his hands and arms with a brush and soap, and dried them on a clean cloth.
5. The cover was removed from the can and the cow milked, the first couple of jets from each teat not being collected. The milker insisted on moistening his hands with milk direct from the teats, but the excess was not collected. Care was taken, so far as possible, to prevent the access of dust and dirt to the pail.

Samples of nine consecutive milkings were taken under these new conditions and examined as before. I was present at all these milkings with the exception of the last, at which the milker was intentionally left to do everything for himself, without assistance.

Table 12 gives the results of the first series of milks, obtained under the old conditions. Total organisms growing on trypagar at 37.5°C. and lactose fermenting bacilli were enumerated. Samples of all the milks were kept in sterile tubes at air temperature and tasted every three hours, between 8 a.m. and 11 p.m., each day. The table records the number of hours old each milk was when it was first found to taste sour.* Table 13 records the same facts for the nine milks obtained under the new and improved conditions.

TABLE 12.

MILKS—OLD CONDITIONS.

Milk Number	1	2	3	4	5	6	7	8	9
Date ...	23/7/20.		24/7/20.		25/7/20.		26/7/20.		27/7/20
Time ...	M.	E.	M.	E.	M.	E.	M.	E.	M.
Total bacteria per c.c. ...	62,000	153,400	66,200	82,600	128,800	51,000	23,800	56,000	89,200
Lactose fermenters per c.c.	500	25	250	50	25	10	25	10	25
Souring time (hours) ...	52	48	58	53	63	75	63	72	58

TABLE 13.

MILKS—NEW CONDITIONS.

Milk Number	10	11	12	13	14	15	16	17	18
Date ...	27/7/20	28/7/20		29/7/20		30/7/20		31/7/20	
Time ...	E.	M.	E.	M.	E.	M.	E.	M.	E.
Total bacteria per c.c. ...	3,780	3,520	2,160	2,500	2,260	1,720	1,300	2,140	3,720
Lactose fermenters per c.c.	0	0	1	0	0	0	0	0	2·5
Souring time (hours) ...	183	181	154	217	207	217	189	193	131

M.—Morning. E.—Evening.

* A sour taste could just be detected in milk when its acidity reached 39 degrees; that is to say 100 c.cs. of such a milk required 39 c.cs. of $\frac{N}{10}$ alkali to render it neutral, phenol phthalein being used as indicator. The acidity of absolutely fresh milk usually lies between 10 and 20 degrees, although sometimes it may be as high as 25 degrees.

Comparison of Results of Old and New Methods.

These tables and Chart 4 demonstrate so clearly the effects of even the simple precautions described above, in producing a purer milk, that little explanation is necessary. The average number of total organisms in each cubic centimetre, under the old conditions was 79,200 and, under the new, 2,570, about one-thirtieth of the first figure. The average number of lactose fermenters in the first series of milks was 102, while in the second these organisms were only found in 1 cubic centimetre on two occasions. The average souring time of the milks in the first series was 60 hours, and, in the second 185 hours, three times as long.

The good results in the second series of milks show that it is quite possible to instruct the typical farm labourer in the necessary precautions to take in order to produce clean milk. The man who milked in this investigation had only instruction for a few minutes at a time, twice daily, for four days, and yet the milk which was obtained on the last occasion, on which he was quite alone and unassisted, showed only a slightly greater degree of contamination than the preceding ones.

On one occasion a small sample of the middle milk was collected into a sterile bottle and tested in order to discover the number of bacteria which were unavoidable. The milk was found to contain 404 organisms per cubic centimetre.

Satisfactory as these results are they could have been still further improved. Some hay and straw were kept in the milking shed throughout the investigation. Their removal would have lessened the amount of bacteria-laden dust in the air of the shed. The shed was not washed for the second series of milkings. The use of a hooded pail, or one with a lateral opening would have given much better results, but the investigation was planned to show the improvements which might be effected without the purchase of any new apparatus. Sterilisation of the pail by steam would, probably, have improved the result, but the use of steam is impossible for most small farmers.

Knight, Freear and Williams (27) have shown clearly, and in detail, the influence, on the number of bacteria in milk, of the type of bucket used, the method of its cleansing and the cleanliness of the cow.

Dry milking would, I am convinced, have given better results, but the milker professed to be sceptical about its possibility and unwilling to attempt this method. Wet milking was, in consequence, practised.

That even better results may be obtained under commercial conditions is shown by the examination of milks from the Moundsmere Farm, owned by Mr. Wilfred Buckley, in which one hundred milking cows are kept. Between November, 1916, and May, 1917, twenty-three milk samples from this farm were examined by Dr. Stenhouse Williams. At the time of the examination the milks were from 18 to 26 hours old, and had been kept at air temperature. The average number of bacteria in these milks was 1,178 per cubic centimetre. In twenty of them lactose fermenters were not found

in 1 c.c. The owner of the farm states (19):—" Any farmer can produce clean milk if he has the necessary determination and if an adequate water supply is available."

Effect of Time and Temperature on the Number of Bacteria in Milk.

The rate of multiplication of bacteria in milk is very variable. Two milks, which contain the same initial number of bacteria, after being kept for the same time, at the same temperature, may give widely divergent bacterial counts, owing to the different rates of multiplication of various types of bacteria.

The following table gives the results of keeping a milk of good quality at temperatures of 8°, 14°, and 21°C. (46°, 57°, and 70°F.). The milk was obtained three hours after milking, was well shaken, and divided into three parts, which were placed in sterile bottles. These were kept at the desired temperature and, at intervals, samples of each were removed and examined.

TABLE 14.

EFFECT OF TIME AND TEMPERATURE ON BACTERIAL CONTENT OF MILK.

Test No.	No. of hours during which Milk was kept at desired temperature.	8°C.		14°C.		21°C.	
		Total bacteria per c.c.	Lactose fermenters per c.c.	Total bacteria per c.c.	Lactose fermenters per c.c.	Total bacteria per c.c.	Lactose fermenters per c.c.
1	0	6,500	1	6,500	1	6,500	1
2	4	4,400	1	5,800	2·5	32,000	5
3	7	6,400	2·5	8,000	2·5	132,000	25
4	10	5,600	2·5	6,200	5	622,000	100
5	22	19,000	5	70,000	50	28,600,000	25,000
6	25	29,000	5	124,000	100	146,000,000	100,000

It will be noticed that, at the low temperatures, there is no appreciable increase in the total organisms for the first ten hours. There even appears to be an indication of some decrease, a phenomenon which has frequently been observed before, but this is not very clear owing to the unavoidable experimental errors of enumeration. At 22 hours and at 25 hours, however, there has been a definite increase which is more noticeable at 14° than at 8°.

In the case of the milk kept at 21°C. throughout, there is no indication of a period of decrease. Instead, the multiplication is constantly going on, and in 25 hours the total organisms number 146 millions and the lactose fermenters one hundred thousand per cubic centimetre.

Savage (8) states that B. coli in milk, in 24 hours at 15°C. will usually show a 100-fold increase or, rarely, as much as a 1,000-fold increase. At 20° to 21°C. in the same time the increase is about 10,000-fold, but less when the initial number of B. coli is very great.

The practical application of the results of the investigations, described above, may be made clear by quoting what Park and Williams (18) have written:—

" Any intelligent farmer can use sufficient cleanliness and apply sufficient cold with almost no increase in expense, ½ cent. per quart, to supply milk twenty-four to thirty-six hours old, which will not contain in each cubic centimetre over 50,000 to 100,000 bacteria, and no milk containing more bacteria should be used."

PART V.

HOW A SUPPLY OF PURE MILK HAS BEEN, AND CAN BE, SECURED.

Milk Commissions in the U.S.A.

For more than twenty years a considerable number of cities and towns in the United States of America have had medical milk commissions. These bodies, which consist, in whole or part, of medical men, are usually chosen by the local medical society. The functions of these commissions are to select the best dairies and to authorise them to apply the term " certified " to the milk which they produce. The advantages of using certified milk are so great and so widely appreciated, especially by medical practitioners, that the milk suppliers have come to realise that it pays those who desire good customers to make their product satisfy the requirements of the commission and so qualify for the use of the term certified. Usually the requirements, before the granting of the right to label their milk as certified to dairymen, include the freedom of the herd from tuberculosis, as judged by tuberculin test, a physical examination of the cows, and inspection of the buildings and other equipment of the dairy and of the method used in producing milk and in transporting it to its selling place.

The New York Milk Commission specifies that milk certified by them must not contain more than 30,000 bacteria in each cubic centimetre. The limit of the Philadelphia Commission is even more strict, viz., 10,000 bacteria per cubic centimetre (28). The majority of the commissions throughout the country have followed that of New York and fixed the maximum number of bacteria permissible in certified milk at their figure—30,000.

Regulations Prohibiting Excessive Bacterial Contamination.

Since the scheme for the certifying of milk was quite optional, and such milk was produced only by those who were sufficiently public-spirited to see its importance from the public health standpoint, or by those whose customers demanded it, many cities have fixed bacterial standards which may not be exceeded without the risk of punishment or of prohibition of the rights of supplying their territory.

The maximum number of bacteria which may be present in milk sold in Boston is 500,000, in Milwaukee 250,000, and in Rochester (New York) 100,000 per cubic centimetre (28). That such limits are possible has been amply proved by the experience of these places.

Milk Regulations of New York City.

Owing to the bad conditions of the milk supply of New York, the Public Health Department issued, in 1914, regulations governing the quality of milk sold in the City (29). Only the best quality of milk is allowed to be sold in its raw state; the lower quality milks must be pasteurised. All milks sold in the city are divided into three grades.

Grade A Milk (raw).—The cows from which this milk comes must be negative to the tuberculin test prior to admission to the herd and subsequently every year. The equipment of the farm and methods used in milk production must have received at least 75 marks out of a possible score of 100. The milk must be supplied to the consumers in bottles within 36 hours after milking and must not contain more than 60,000 bacteria in each cubic centimetre.

Grade A Milk (pasteurised).—All cows of the herd must be found healthy on annual physical examination. The score for equipment and methods must be at least 68 per cent. The milk must be supplied in bottles, within 36 hours of pasteurising. It must not contain, in each cubic centimetre, more than 200,000 bacteria before, and 30,000 after, pasteurisation.

Grade B Milk (pasteurised).—The regulations as to the health of the herd are the same as for the last grade. The minimum score is 55 per cent. The milk must be supplied, in cans or bottles, within 48 hours of pasteurisation, and must not contain more than 1,500,000 bacteria before or 100,000 after, in each cubic centimetre.

Grade C Milk (pasteurised).—This milk is for use in cooking only. The regulations are similar to those for Grade B, but the milk is to be supplied in cans only. No limit (within reason) is made for the milk before pasteurisation, but subsequently it must not contain over 300,000 bacteria per c.c.

The regulations also give details of the methods of making the tuberculin test, of counting the score for equipment and methods, and prescribe the types of bottles and cans to be used and how they are to be labelled.

Pure Milk Regulations in England.

The Ministry of Food and the Ministry of Health in England have drawn up regulations which must be complied with by those wishing to supply good quality milk under the names " Grade A Milk " and " Grade A (certified) Milk." These regulations enforce the tuberculin testing of the cows in the herd from which the milk comes. The equipment and methods of the farm and the health of the cows must be found satisfactory on inspection. Grade A (certified) milk must be cooled and bottled immediately at the place of production. It must be sold within two days and must at no period contain B coli in 1/10 c.c. (in each of two tubes) or more than 30,000 bacteria per c.c. Grade A milk must be supplied in bottles, but need not necessarily be bottled immediately after its collection. No bacterial standards have been made for this milk.

The Position of Ireland.

As yet Ireland has no regulations limiting the number of bacteria which milk may contain and continue to be sold as suitable for infants; nor has she any scheme under which it can be guaranteed that any particular milk is of good quality. For so long as the

law allows farmers to produce and retailers to sell dirty milk, and the public does not refuse to have such milk, for just so long will it continue to be sold.

If water is added to milk, or fat abstracted from it, the law is broken and a penalty, usually far too light, is inflicted. But dirt may be allowed to gain access to the milk with impunity; and this, in the eyes of a hygienist, is a much more criminal matter. There can be no discussion as to the relative wickedness of two men, the one of whom steals a little of a baby's food, while the other permits poison to be added to the food which remains. The one is merely a thief, the other an actual or potential murderer. Those who supply and sell dirty milk to the children of Dublin are responsible for the death of hundreds each year.

It is unfortunate that excessive bacteria produce so little change in milk, unless it is kept for too long a time. Milk may contain fifty million bacteria in each cubic centimetre or more than two and a half million in each drop, a number sufficient to cause a distinct turbidity if added to pure water, and yet neither taste nor look unpleasant. The public has learned to detect any gross addition of water to milk, but it cannot be taught to detect excessive bacterial contamination. It may, nevertheless, be instructed sufficiently to appreciate the dangers of this contamination. Satisfactory water supplies have been procured for every large community in Ireland, and it is quite time that a similarly satisfactory milk supply was made available. If there is a general public demand for pure milk, that demand can be, and will be, met by those who supply our milk. My investigations at the farm have shown that milk of an excellent quality can be produced at an expenditure of some soap and water, some time and some thought. Any farmer, if willing, can learn in two or three hours, how to produce milk which is infinitely superior to 95 per cent. of that sold in Dublin to-day.

How are we to secure a pure milk supply for Dublin or for any city or town in Ireland? I cannot believe that persuasion will, in the majority of cases, do much good. It has been tried for many years and has failed. I would, however, feel well satisfied if, as the outcome of this labour, even two or three large farmers could be persuaded to attempt the production of pure milk in order to supply the needs of our cities.

It seems to me that, to put it crudely, farmers will only attempt to produce pure milk if they are persuaded to do so, or if they are punished for failing to do so. In other words, pure milk must pay better than dirty milk, or those who produce dirty milk must be fined, imprisoned, or prohibited from supplying milk to the city.

Pure Milk is Worth More than Dirty Milk.

Almost every article we buy, except milk, is priced according to its quality, and, as a general rule, the higher the price the better the quality of the goods. Milk, however, is always regarded as

merely milk, and the same price is charged for clean as for dirty milk. I think, therefore, that some standard should be established, and that any milk superior in quality to it should be sold at a slightly higher price than the ordinary quality. Milk is to-day an expensive food and no steps should be taken, rashly, which would have the effect of still further raising its price. But, in the interests of clean milk, a slight increase would be justified. Freear, Buckley and Williams (30), in 1919, calculated that the production of a satisfactory clean milk, in churns, added about threepence a gallon to its market price. Suppose that now the extra expense and labour involved in the production of clean milk would increase the cost by double this amount, sixpence a gallon, I think that the benefits of such a milk would be worth the increased cost. Williams (31), as the result of an investigation of the wastage of milk coming to English cities, estimated that 1 or 2 per cent. of all the milk was wasted through souring. Probably wastage, in Ireland, is less than this, but there is a very large amount of domestic wastage, that is of milk brought into the house by the consumer and turning sour before it is used. A clean milk will not sour under any ordinary conditions met with in this country, within 36 hours of milking, if it be kept clean.

Milk is sold in Dublin, at present, at 4½d. to 5d. a pint. An additional 6d. a gallon will bring the cost of the milk now sold at 4½d. up to 5¼d. a pint. In other words, an amount of milk which now costs 6d. would, at the higher rate, cost 7d. In order to keep the domestic expenditure the same as at present the daily ration of milk would have to be decreased by one-seventh. This would inflict no hardship, as there would be no waste through souring, and infants would thrive better on six parts of pure milk than on seven of the dirty fluid now supplied as milk.

The suggestion of sixpence a gallon increase is to be regarded as a maximum; the equitable amount must be decided by one skilled in agricultural conditions. However, the right to charge more for pure milk having been conceded, what are we to demand in return? The following are the essentials:—

Suggested Regulations for a Pure Milk Supply.

1. The herd must be free from tuberculosis, as judged by tuberculin test. Annual tests must be made and reactors removed.

2. The physical condition of all cows must be satisfactory on six monthly veterinary examination.

3. The cow sheds, milking sheds, and dairy must be suitable, and must be kept thoroughly clean.

4. The equipment must be of approved design and capable of proper cleaning.

5. The methods of milking and of dealing with the milk must be open to inspection and must be found satisfactory.

6. No milk may be more than 24 hours old at the time it is sold.

7. Milk must be cooled immediately after collection and must not be at a higher temperature than 55°C. subsequent to this.

8. Facilities must be allowed for taking samples of milk for bacteriological and chemical examination.

9. No milk may contain more than 100,000 bacteria, capable of growing at body temperature, in each cubic centimetre. Lactose fermenting bacilli must not be present in two tubes to each of which has been added 1/25 c.c. of milk.

The standards suggested, and some of the conditions, have been made considerably more lenient than those adopted in England, for here we have few, if any, individuals to whom dairying is more a hobby than a means of livelihood.

The conditions are capable of being fulfilled, and the standards should not be exceeded, by any farmer fit to be in the milk trade. Even under the present system, 32 per cent. in winter and 14 per cent. in summer of the milks examined fall below the maximum number of bacteria permitted, while 12 per cent. in winter and 6 per cent. in summer fall within the specified limits for lactose fermenters.

The question of bottling has not been touched on for several reasons. The initial outlay, the cost of renewal, and the cost of the necessary apparatus for cleaning and steaming, are all very considerable. Bottled milk, if the bottling is well done, is excellent, but unless well done is better unattempted; and I fear that no one can be found in Ireland willing to risk the necessary expenditure. Further, bottling would still more increase the cost of the clean milk.

Probably the most satisfactory method of supplying the milk to the consumers would be to have the milk distributed, immediately after cooling and straining, into small cans containing one and two pints each. These should be sealed, with a paper seal, and delivered to the consumer with the seal intact. This method would involve a considerable expenditure for the cans, but, if each customer was required to make a deposit, or to purchase one or more cans outright, the loss would be nil and the renewal expense very small. Failing this, churns of a proper pattern might still be used, both for selling from carts and in shops. In the latter case the milk should be sold direct from the churn. The open can, from which the milk is removed with a dipper, should not be permitted. It too easily allows the addition of dirt, water, and milk of unknown quality from some other source. While the pattern used on milk-carts, from which the milk is taken by way of a tap, is difficult to clean, it is at least preferable to the other kind mentioned above. The tap should be protected from dirt by a flap which closes when the tap is not being used.

The above are to be regarded merely as suggestions, which may be modified before they are practically applied, and which may be improved in many directions subsequently. If milk producers can be found willing to attempt to comply with them, I believe that

they will be found to be neither unduly irksome nor burdensome. They would guarantee to the public that milk which complied with the regulations was of good quality and would be unlikely to injure infants or young children.

Having suggested means by which good milk could be produced and tested, are we to permit those unwilling to comply with the regulations to sell dirty milk? I feel strongly that to allow some of the milks which I have tested to be sold for food is absolutely wrong. They show clearly an utter disregard for cleanliness in some, probably in every, stage of their collection or distribution. If the farmer says that he cannot produce cleaner milk, he should no longer be allowed to sell any milk.

Suggested Maximum Standards.

I would fix 2,500,000 bacteria and 5,000 lactose fermenters per c.c. as the maximum numbers permitted in any milk sold. These are very lenient standards and compare unfavourably with those adopted for other cities. The suggested maximum for total bacteria is five times that of Boston and twenty-five times that of Rochester (New York). It exceeds by one million the number allowed to be present in Grade B milk in New York before it is pasteurised. Savage's suggested maximum figures for lactose fermenters were 100 to 500 in winter, and 1,000 to 2,500 in summer. It will, therefore, be seen that the standards are by no means exacting, especially for Dublin, where the greater portion of the milk is produced either in the city or in its close vicinity. It was thought better, however, to commence with low standards, which might afterwards be improved, in order that there might be as little dislocation of the milk trade as possible. 25 per cent. of the milks examined exceeded the maximum number of bacteria, and 20 per cent. contained more than the permissible number of lactose fermenters. Nevertheless, there is no reason why these milks, unless they had been kept too long, should not have passed this test, except for the carelessness of the producers or sellers of them.

Tubercle Bacilli.

Care must also be devoted to the problem of tubercle bacilli in milk. To rid the country of tuberculous cattle would be a difficult, tedious and expensive task, but, at least, every effort should be made to prevent milk containing tubercle bacilli from being sold raw. Tuberculosis in cattle may be diagnosed by tuberculin, and tubercle bacilli can be found fairly easily in milk. These are the two weapons which must be used in fighting tuberculosis of bovine origin in man and animals. That the useful life of a cow is not much more than seven years, and that diseased animals may be slaughtered, are two factors which should make bovine tuberculosis more easily conquered than the human form.

Effect of Suggested Regulations on the Milk Trade.

These suggestions for the reform of the conditions of milk production and milk distribution may put a few small producers out of business, although I see no reason why they should. Even if this does occur, the diminution in the milk supply will not be significant. They probably, however, will have the effect of debarring a number of small retailers from dealing in milk, and that is no drawback, but rather the reverse. No food is so easily contaminated, by lack of cleanliness, as milk, and in none other are the results of contamination so serious. We can prevent the greater part of the contamination at the farm, and we must also prevent that lesser, but still important, contamination which occurs in the shop of the retailer. Milk for sale must be kept cool, in clean vessels, covered and protected from flies, dust and dirt. At present milk is sold in many shops where no effort is made to protect it in any way, or to keep it under proper conditions.

Those who retail, just as those who produce, milk have depending on their care the lives of many infants and, therefore, it is necessary that many of the inefficient small dealers should go and be replaced by shops in which milk, and only milk, is kept and sold in such a way that no avoidable contamination gains access to it.

Necessary Domestic Precautions.

Finally, if pure milk is supplied, it is the duty of the housewife to keep it pure for use. A few drops of the previous day's milk, in an unwashed jug, will be sufficient, in hot weather, quickly to turn sour the whole of the fresh milk. The remedy is not difficult, for boiling water, while it will not kill all bacteria immediately, will kill almost all those commonly found in milk, in a short time. Therefore wash all milk vessels thoroughly, and then scald them with really boiling water, keep milk covered and so protected from dust and flies, and keep it in the coolest place possible.

APPENDIX 1.

Results of Examination of One Hundred Dublin Milks.

Number.	Month.	Ward of City in which bought.	Source.	Temp. (°C.)	Bacteria per c.c.	Lactose Fermenters in 1 c.c.	Streptococci in 1 c.c.	Spores in 20 c.cs.
1	January ...	North City ...	City ...	8	980,000	5,000	100,000	2
2	,, ...	Inns Quay ...	,, ...	13	360,000	50	50,000	1
3	,, ...	Mountjoy	,, ...	11	396,000	100	50,000	1
4	,, ...	,, ...	,, ...	13	190,000	50	50,000	0
5	,, ...	,, ...	,, ...	12·5	94,000	50	10,000	2
6	,, ...	,, (cart) ...	Finglas ...	12·5	284,000	100	50,000	0
7	,, ...	,, ...	City ...	14	32,000	50	10,000	0
8	,, ...	,, ...	,, ...	9·5	1,300,000	500	500,000	3
9	,, ...	Rotunda	Tallaght ...	12	98,000	50	5,000	1
10	,, ...	Mountjoy	City ...	11	106,000	500	10,000	2
11	,, ...	Trinity	,, ...	10	35,000	500	1,000	1
12	,, ...	,, ...	,, ...	10·5	5,360,000	1,000	500,000	3
13	,, ...	,, ...	,, ...	12	362,000	1,000	50,000	10
14	,, ...	Wood Quay ...	,, ...	13	432,000	10	50,000	6
15	February ...	Mansion House ...	,, ...	14	96,000	1,000	10,000	2
16	,, ...	Merchant's Quay ...	,, ...	9	56,000	100	10,000	3
17	,, ...	Fitzwilliam ...	Tallaght ...	10	568,000	1,000	50,000	1
18	,, ...	,, (railway)	D. & S. E. Ry.	9	3,140,000	100	500,000	4
19	,, ...	,, ,, ...	,, ...	11	594,000	100	10,000	2
20	,, ...	Mountjoy	City ...	15	620,000	50	10,000	2
21	,, ...	,, ...	Drogheda ...	8·5	116,000	5,000	5,000	6
22	,, ...	North Dock ...	City ...	11·5	108,000	10	50,000	2
23	May ...	Mountjoy	Santry ...	21	1,860,000	1,000	50,000	1
24	,, ...	,, ...	City ...	19	3,980,000	1,000	50,000	0
25	,, ...	,, ...	,, ...	18	4,220,000	25,000	50,000	1
26	,, ...	,, ...	Crumlin ...	20	28,800,000	500	500,000	1
27	,, ...	North Dock ...	Fairview ...	17	820,000	500	100,000	4
28	,, ...	,, ...	City ...	18	760,000	500	100,000	10
29	,, ...	Mountjoy	,, ...	19·5	1,100,000	100	500,000	2
30	,, ...	North Dock ...	Clontarf ...	18·5	240,000	50	100,000	3

APPENDIX 1.—*continued.*

Results of Examination of One Hundred Dublin Milks.—*continued.*

Number.	Month.	Ward of City in which bought.	Source.	Temp. (°C.)	Bacteria per c.c.	Lactose Fermenters in 1 c.c.	Streptococci in 1 c.c.	Spores in 20 c.cs.
31	May ...	St. George's (cart) ...	City ...	18	90,000	100	10,000	2
32	,, ...	Inns Quay ...	Santry ...	17	64,000	10	10,000	4
33	June ...	Rotunda	City ...	15·5	428,000	500	100,000	0
34	,, ...	,, ...	,, ...	14·5	2,120,000	10,000	500,000	1
35	,, ...	Inns Quay	Fairview ...	18	13,000,000	500	500,000	0
36	,, ...	St. George's ...	Santry ...	20	700,000	500	50,000	4
37	,, ...	,, (cart) ...	City ...	18·5	560,000	1,000	100,000	0
38	,, ...	,, ,, ...	,, ...	18	54,000	50	10,000	1
39	,, ...	Royal Exchange ...	,, ...	19	28,000	10	10,000	0
40	,, ...	Mansion House ...	,, ...	18·5	346,000	500	10,000	3
41	,, ...	,, ,, ...	,, ...	19	13,200,000	500	1,000,000	1
42	July ...	Royal Exchange ...	,, ...	18	132,000	50	100,000	3
43	,, ...	Merchant's Quay ...	,, ...	18·5	1,420,000	500	50,000	0
44	,, ...	,, ,, ...	,, ...	18	360,000	10	100,000	1
45	,, ...	Usher's Quay ...	,, ...	21	6,200,000	100	1,000,000	3
46	,, ...	Merchant's Quay ...	,, ...	16·5	13,200,000	10,000	1,000,000	1
47	,, ...	Fitzwilliam (cart) ...	Rathfarnham ...	20	3,820,000	250	500,000	0
48	,, ...	St. George's (cart) ...	City ...	19·5	196,000	250	100,000	0
49	,, ...	North Dock ...	Pembroke ...	20	27,800,000	100,000	1,000,000	2
50	August ...	Fitzwilliam (D.&S.E.R.)	Wicklow ...	20	58,400,000	250,000	1,000,000	1
51	,, ...	Mountjoy	City ...	18·5	6,200,000	5,000	1,000,000	3
52	,, ...	,, ...	Rathfarnham	19·5	73,200,000	250,000	1,000,000	9
53	,, ...	North Dock ...	Drogheda ...	21	23,000,000	50,000	1,000,000	1
54	,, ...	Royal Exchange ...	Dundrum ...	18·5	5,200,000	500	100,000	1
55	,, ...	Fitzwilliam (cart) ...	Finglas ...	19	2,660,000	50,000	10,000	1
56	,, ...	Mansion House (cart)	Dundrum ...	18·5	700,000	50	10,000	2
57	,, ...	Mountjoy	City ...	18·5	2,200,000	250	500,000	2
58	,, ...	,, ...	,, ...	19·5	940,000	5,000	100,000	2
59	September ...	,, ...	Drogheda ...	14·5	10,200,000	50,000	1,000,000	4
60	,, ...	Inns Quay ...	Coolock ...	19·5	100,000	50	10,000	0
61	,, ...	Rotunda	City ...	19	2,560,000	250,000	1,000,000	2

62	,, ...	,, ...	Aughrim ...	17	480,000	250	50,000	3
63	,, ...	Merchant's Quay ...	Rathfarnham	15·5	2,220,000	250	500,000	1
64	October ...	Usher's Quay ...	Co. Cork ...	17	14,800,000	250,000	1,000,000	2
65	,, ...	,, ,, ...	Clondalkin ...	17·5	10,000,000	5,000	100,000	0
66	,, ...	Merchant's Quay ...	Woodenbridge	10·5	198,000	250	100,000	2
67	,, ...	,, ,, ...	City ...	15	42,000	50	10,000	6
68	,, ...	,, ,, ...	,, ...	15	820,000	500	100,000	6
69	,, ...	Inns Quay ...	,, ...	15	420,000	250	100,000	1
70	,, ...	Arran Quay ...	,, ...	12	24,000	250	1,000	0
71	,, ...	Coolock	,, ...	13·5	500,000	100	50,000	2
72	November ...	Rotunda	,, ...	13	1,160,000	1,000	500,000	8
73	,, ...	Inns Quay ...	,, ...	14	2,500,000	50	1,000,000	4
74	,, ...	,, ,, ...	,, ...	15·5	320,000	100	10,000	3
75	,, ...	Merchant's Quay ...	,, ...	15	7,080,000	10,000	1,000,000	2
76	,, ...	Usher's Quay ...	,, ...	16·5	480,000	1,000	100,000	2
77	,, ...	,, ,, ...	,, ...	17	640,000	1,000	500,000	7
78	,, ...	South Dock ...	Pembroke ...	13	220,000	50	5,000	1
79	,, ...	Trinity	Aughrim ...	7	58,000	500	1,000	0
80	,, ...	,, ...	City ...	10	34,000	10	5,000	1
81	,, ...	Royal Exchange ...	,, ...	8	358,000	100	100,000	2
82	,, ...	,, ,, ...	,, ...	5·5	9,600,000	100,000	1,000,000	1
83	,, ...	,, ,, ...	,, ...	10·5	74,000	5	10,000	1
84	,, ...	Inns Quay ...	,, ...	13	18,000	50	10,000	7
85	,, ...	,, ,, ...	,, ...	11·5	60,000	100	10,000	4
86	,, ...	,, ,, ...	Drogheda ...	8	64,000	5	10,000	2
87	,, ...	,, ,, ...	City ...	14	12,200	100	1,000	3
88	,, ...	Mountjoy	,, ...	11	5,580,000	10,000	1,000,000	0
89	,, ...	Inns Quay ...	,, ...	14·5	828,000	1,000	100,000	0
90	December ...	South City ...	Rathfarnham	13·5	24,000	25	5,000	1
91	,, ...	Wood Quay ...	City ...	14·5	310,000	250	100,000	3
92	,, ...	,, ,, ...	,, ...	12	34,000	25	1,000	0
93	,, ...	Mansion House ...	Rathnew ...	10	3,220,000	50,000	1,000,000	1
94	,, ...	Arran Quay ...	City ...	10	226,000	1,000	50,000	2
95	,, ...	Mansion House ...	,, ...	15·5	158,000	50	50,000	0
96	,, ...	North City ...	,, ...	8·5	102,000	250	50,000	2
97	,, ...	North Dock ...	,, ...	9	374,000	100	100,000	4
98	,, ...	North City ...	,, ...	8	22,000	10	1,000	1
99	,, ...	Inns Quay ...	,, ...	16	1,400,000	100	100,000	2
100	,, ...	,, ,, ...	Terenure ...	14	260,000	100	50,000	1

Appendix 2.

METHODS OF EXAMINATION OF MILK.

Dilution of Milk.

By means of a 10 c.c. pipette, 9 c.cs. of saline were measured into each of a number of test-tubes, which were arranged in a rack, in the first space of which an empty test-tube was placed. The milk in the bottle was well shaken and some was transferred by a pipette to the first empty tube. From this 1 c.c. of milk was taken and transferred to the first tube containing saline. This pipette was returned to the milk tube and, with a fresh one, the milk and saline were mixed and 1 c.c. of the mixture was transferred to the third tube. This operation was repeated for each tube, until the highest dilution required had been reached, a fresh pipette being used for each tube. All the tubes, pipettes and saline used in the making of the dilutions had previously been sterilised.

Tube	1	contained								Milk undiluted.
,,	2	,,	1 c.c.	from	tube	1+	9 c.cs.	saline	=1/10	milk
,,	3	,,	,,	,,	,,	2+	,,	,,	=1/100	,,
,,	4	,,	,,	,,	,,	3+	,,	,,	=1/1000	,,
,,	5	,,	,,	,,	,,	4+	,,	,,	=1/10000	,,
,,	6	,,	,,	,,	,,	5+	,,	,,	=1/100000	,,
,,	7	,,	,,	,,	,,	6+	,,	,,	=1/1000000	,,

Estimation of Total Organisms.

0.5 c.c. of each dilution of milk, or of such dilutions as experience had shown to be advisable, was added to a tube containing trypagar (Ph. 7.5) which had been melted and cooled to 46°C. The tube was rolled between the hands to mix the contents, which were then poured into a sterile Petri dish. The plates made in this way were marked with the number of the milk and the dilution, and were incubated at 37.5°C. for 48 hours. The plates made from each milk were examined, and one was chosen for counting. The selected plate should contain as large a number of colonies as could be counted with certainty, preferably between 100 and 300. In order to facilitate counting, the bottom of the plate was marked off into a number of areas (8, 16, or 24) with glass ink. The number of colonies in each area was counted, and the sum of these gave the total for the plate. Counting was done against daylight from a window, a hand lens being used to verify doubtful colonies. The number of colonies on the plate multiplied by the dilution, multiplied by 2 (for only 0.5 c.c. of the dilute milk was added to the agar) gave the number of bacteria, capable of growing on agar at body temperature, in each cubic centimetre of the milk. If, for instance, 0.5 c.c. of the 1/10,000 dilution of a milk had been added to a tube of agar, and the resulting colonies numbered 273, the total bacteria in that milk would have been 273 x 2 x 10,000, or 5,460,000 per c.c.

Lactose Fermenting Bacilli (B. coli, B. acidi lactici and B. lactis aerogenes).

1.0, 0.4, and 0.2 c.cs. of each dilution of the milk were added to tubes fitted with Durham gas tubes and containing lactose bile-salt broth with Andrade's indicator. The tubes were marked and

incubated at 37.5°C. for 48 hours, when inspection showed in which tubes acid and gas had been produced. Although all the tubes from the first one up to a certain one in the series usually showed acid and gas production, and the succeeding tubes no change, irregularities sometimes appeared. For example, the tubes containing 1 c.c., 0.4 c.c. and 0.2 c.c. of the 1/10 dilution and 1 c.c. of the 1/100 dilution might show the change, those containing 0.4 c.c. and 0.2 c.c. of the 1/100 dilution being unaltered and that with 1.0 c.c. of the 1/1,000 dilution being positive. In such cases the last tube of the series in which no unchanged tubes had occurred was taken as the last positive. In the instance given the last positive tube would be taken as the one containing 1 c.c. of the 1/100 dilution. In order to establish the nature of organism fermenting the lactose in this tube, a small amount of its contents was spread on the surface of a lactose bile-salt neutral red agar plate which was incubated for 24 hours. Red (i.e., lactose-fermenting) colonies were filmed and stained, and those found to consist of Gram-negative bacilli were again subcultured into lactose broth to see if they produced acid and gas. If this change occurred, the presence of a Gram-negative, lactose fermenting bacillus in the tube examined had been proved. Failure to isolate such an organism forced one to test other tubes which showed acid and gas, in the same way, until one was found which contained an organism possessed of the desired characteristics. The amount of milk added to the tube thus finally selected, was taken to have in it one lactose fermenting bacillus. The results were expressed as numbers of such bacilli per cubic centimetre. If, for instance, it was found that such bacilli were present in 0.4 c.c. of the 1/100 dilution of milk, it was stated that the original milk contained 250 bacilli of this type in each cubic centimetre.

The following table gives the amount of milk in each tube, and the equivalent number of lactose fermenting bacilli per cubic centimetre:—

Tube No.	Amount added (c.c.)	Milk dilution.	Lactose fermenters per c.c.
1	1·0	Undilute	1
2	0·4	,,	2·5
3	0·2	,,	5
4	1·0	1/10	10
5	0·4	,,	25
6	0·2	,,	50
7	1·0	1/100	100
8	0·4	,,	250
9	0·2	,,	500
10	1·0	1/1,000	1,000
11	0·4	,,	2,500
12	0·2	,,	5,000
13	1·0	1/10,000	10,000
14	0·4	,,	25,000
15	0·2	,,	50,000
16	1·0	1/100,000	100,000
17	0·4	,,	250,000
18	0·2	,,	500,000

Streptococci.

1.0 c.c. and 0.2 c.c. of the various dilutions of milk were added to tubes containing 1 per cent. of glucose and 1 per cent. of a 1 per cent. aqueous solution of neutral red. The tubes were incubated for 48 hours at 37.5°C. and examined. A drop of the deposit from the bottom of those tubes showing growth was removed with a capillary pipette, placed on a microscope slide and covered with a cover-glass. The preparation was then examined with a microscope to determine the presence or absence of streptococci. The same regard was paid to consistency as in the case of the lactose fermenting bacilli.

The series of dilutions with the equivalent number of streptococci per cubic centimetre is given in the following table :—

Tube No.	Amount added (c.c.)	Milk dilution.	Streptococci per c.c.
1	1	Undilute	1
2	0·2	,,	5
3	1	1/10	10
4	0·2	,,	50
5	1	1/100	100
6	0·2	,,	500
7	1	1/1,000	1,000
8	0·2	,,	5,000
9	1	1/10,000	10,000
10	0·2	,,	50,000
11	1	1 100,000	100,000
12	0·2	,,	500,000
13	1	1/1,000,000	1,000,000
14	0·2	,,	5,000,000

Spores of Anaerobic Gas-forming Bacteria (B. enteritidis sporogenes* and B. butyricus).

2 c.c. of undiluted milk were measured into each of ten small empty sterile test-tubes. These were heated in a water bath, at 80°C. for ten minutes, to kill non-sporing bacteria. They were rapidly cooled and incubated anaerobically in a McIntosh and Fildes jar. At the end of 48 hours the tubes were examined with the naked eye. The presence of sporing bacteria in the milk was recognised by the characteristic changes produced—separation of the milk into clear whey and coagulated casein, which was torn, as was also the cream on the surface, by the abundant evolution of gas. The result was expressed as a number, the number of tubes out of the ten used which showed this change, and this may be taken as the number of spores in 20 c.cs. of milk.

Tubercle Bacilli.

120 c.cs. of milk were centrifugalised for half an hour, at about 4,000 revolutions per minute in a Delépine centrifuge. The cream

* This organism is either the same as, or is very closely related to, B. welchii (B. perfringens).

and supernatent milk were poured off, and the deposit in the bottom of the tube was emulsified in 2 c.cs. of sterile saline. This was injected, subcutaneously, into the thighs of two guinea-pigs. If the animals survived, they were killed at the end of six weeks, and a *post-mortem* examination made. Material from any suspicious lesions, such as local abscesses, caseous glands, and nodules in the spleen and liver, was made into films stained by the Ziehl-Neelsen method and examined. No guinea-pig was accepted as tubercular unless characteristic acid and alcohol fast bacilli could be found in lesions which, to the naked eye, resembled those due to tubercle bacilli.

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REFERENCES.

1. Houston—"Report of a Bacteriological Investigation of the City of Dublin Milk Supply" 1918
2. Park—Journal of Hygiene 1901
3. Schroeder—Journal of Infectious Diseases 1912
4. Hewlett—A Manual of Bacteriology 1918
5. Williams—"Concerning Infant Feeding." The Medical Officer ... 1918
6. Cunningham and Thorpe—"The Milk Supply of the City of Edinburgh." Journal of Hygiene. 1920
7. Kanthack and Sladen—The Lancet 1899
8. Savage—Milk and the Public Health 1912
9. Anderson—Bulletin No. 41, Public Health and Marine Hospital Service, U.S.A. 1908
10. Hess—"The Incidence of Tubercle Bacilli in the New York City Milk." Journal of the American Medical Association ... 1909
11. Campbell—"Tubercle Bacilli in Market Milk in Philadelphia." Report of Bureau of Animal Industry, U.S.A. 1909
12. Savage—The Medical Officer 1910
13. Lane Claypon—Milk and its Hygienic Relations 1916
14. Report of the Medical Officer to the London County Council ... 1913
15. Grund and Wilcox—"The Frequency of B. Tuberculosis in the Market Milk of New York City." Report of the Department of Public Health in the City of New York ... 1912–1913
16. Mitchell—(*a*) "The Prevalence of Tubercle Bacilli in the Edinburgh Milk Supply"; (*b*) "A Bacteriological Study of Tuberculosis of the Lymph Glands in Children." Journal of State Medicine 1915
17. Schüder—Zeit. f. Hyg. 1901
18. Park and Williams—Pathogenic Microörganisms 1920
19. Buckley—Farm Records and the Production of Clean Milk at Moundsmere 1917
20. Royal Commission on Tuberculosis, 3rd Interim Report 1909
21. Transactions of British Congress on Tuberculosis 1901
22. Transactions of 6th International Congress on Tuberculosis, Washington 1908
23. Park and Krumwiede—"The Relative Importance of the Bovine and Human Types of Tubercle Bacilli in the different forms of Human Tuberculosis." Studies from the Research Laboratory Department of Health, New York City 1910
24. Eastwood and Griffith—"The Characteristics of Tubercle Bacilli in Human Bone and Joint Tuberculosis." Journal of Hygiene ... 1916
25. Griffith—The Lancet 1917
26. Royal Commission on Tuberculosis, 2nd Interim Report 1907
27. Knight, Freear, and Williams—"A Study of Factors concerned in the Production of Clean Milk" 1920
28. Jordan—General Bacteriology 1914
29. Hiss and Zinsser—A Text Book of Bacteriology 1918
30. Freear, Buckley and Williams—"A Study of two Types of Commercial Milk" 1919
31. Williams—"Wastage of Milk." Journal of the Royal Agricultural Society 1918

(14935). Wt. 14355. 3, 3, 3, 500. 6/21. A. T. & Co., Ltd.

CHART 1

AVERAGE NUMBER OF TOTAL BACTERIA FOR EACH MONTH

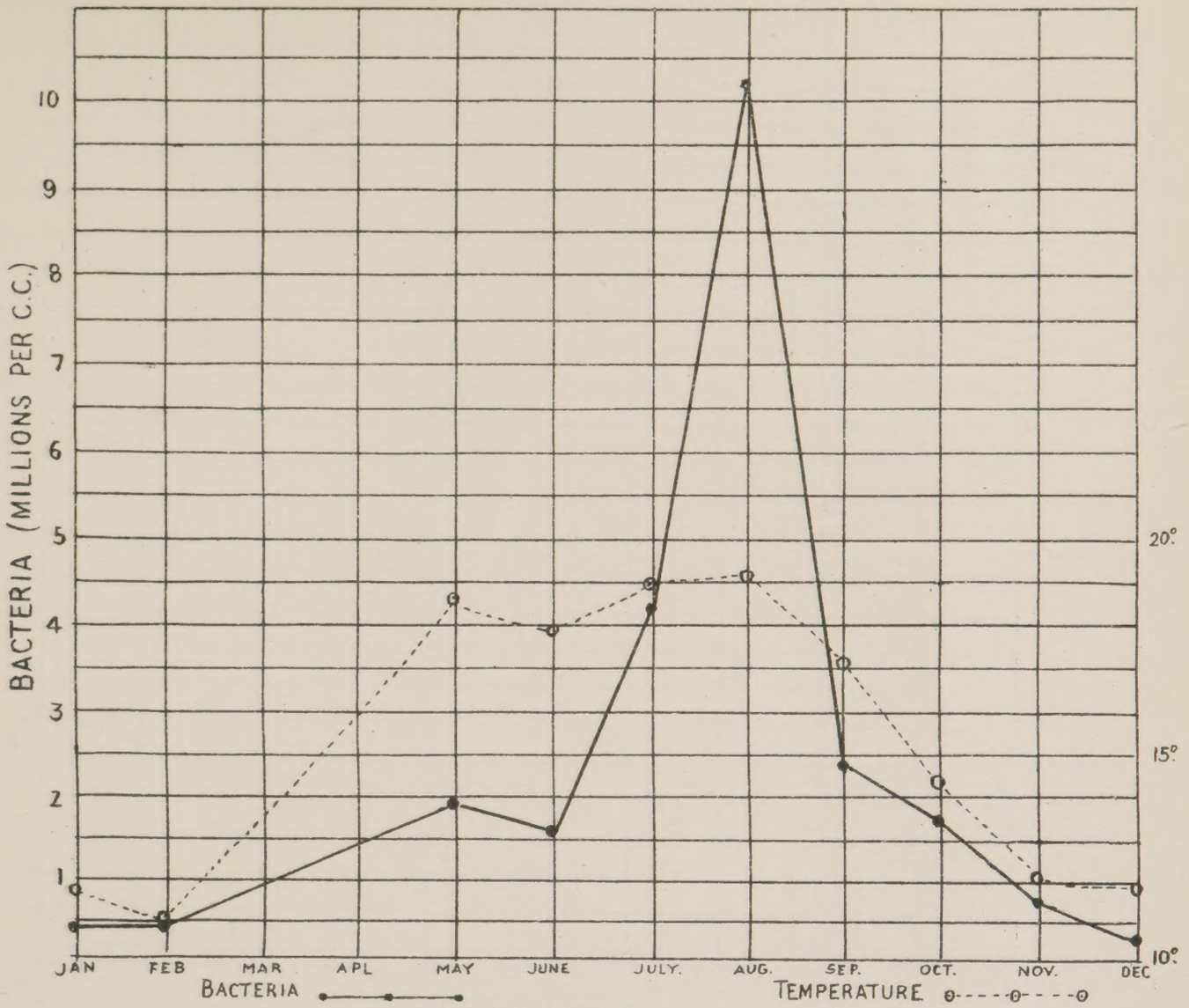
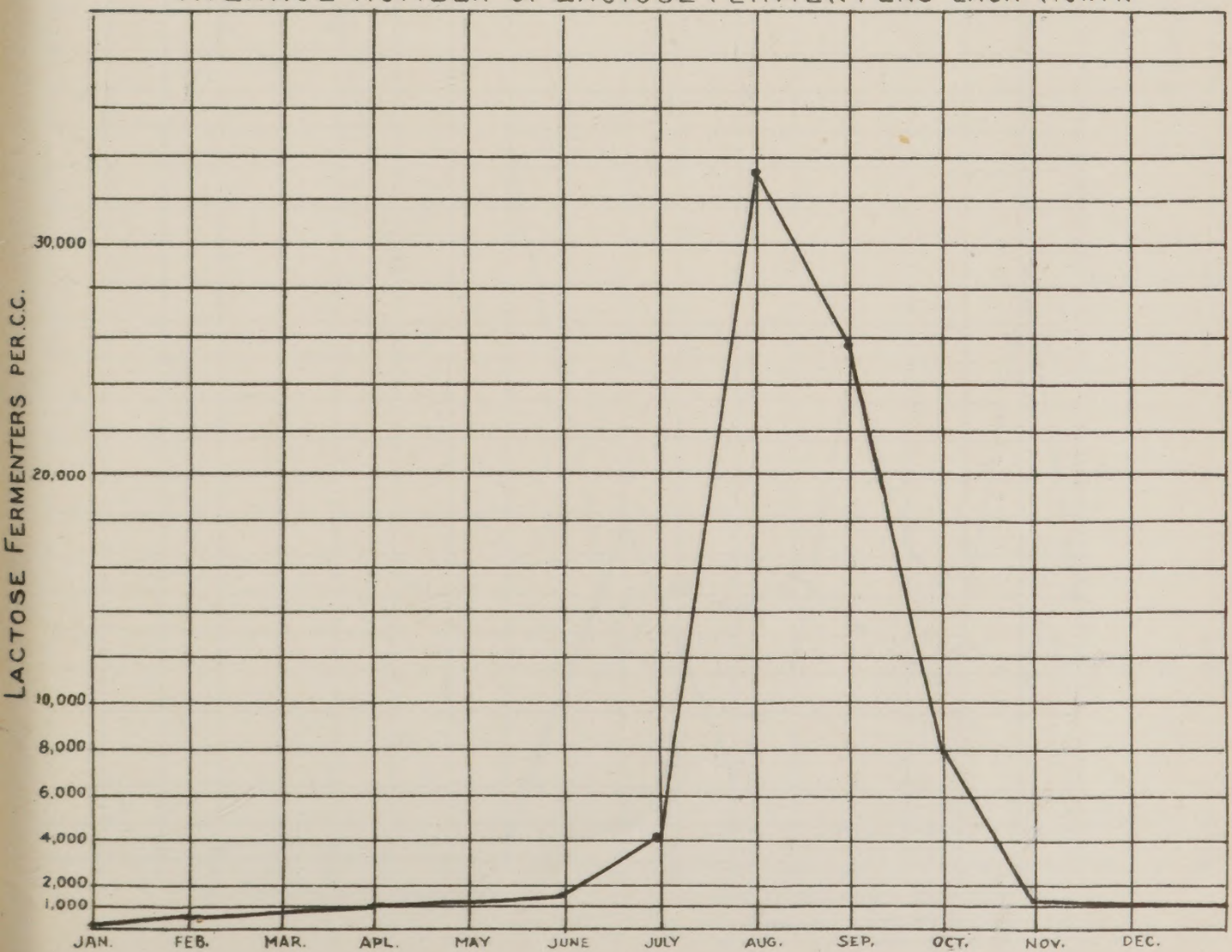


CHART 2

AVERAGE NUMBER OF LACTOSE FERMENTERS EACH MONTH



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